The Long-Term Impact of Metal Smelting Operations on Arsenic Availability in Urban Lakes of the South-Central Puget Sound Region

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Research Team
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Importance of Urban Lakes
• Human population concentrated in urban areas; already 50% or greater worldwide
• Urban poor rely on local, inexpensive, recreational water resources
• Some rely on water sources for culture and diet augmentation
• Urban waters serve as critical habitat for multiple species

Urbanization & Arsenic Pollution
• Lake sediments act as As reservoirs after external source removal
• If remobilized periodically As may migrate to surface sediments
• Cultural eutrophication can exacerbate As release from sediments
• Other anthropogenic inputs may affect As mobility (e.g. road salt, nitrate and phosphate)

Major Sources of Arsenic in Lakes
• Herbicide applications in lakes
• Fruit orchard insecticides
  [Paris Green = 3Cu(AsO2)2.Cu(C2H3O2)2]
• Chemical manufacture
• Timber treatment (CCA)
• Mine tailings and drainage
• Stack emissions
• Slag disposal

ASARCO
• 1890 Lead smelting begins
• 1905 Conversion to copper smelter
• 1912 Arsenic recovery begins in Tacoma
• 1917 Tall stack constructed (700 ft asl) + Electrostatic precipitators
• 1970 Meteorological Curtailment Program
• 1986 All smelting operations cease
Ongoing Study Breakdown

- Spatial distribution of As and Pb in lake sediments
- Temporal distribution in sediments
- Arsenic mobility and release to water column
- Chemical, biological, and physical controls on As mobility, bioavailability, and toxicity

Lakes Sampled

- American Lake
- Spanaway Lake
- Steilacoom Lake
- Snake Lake
- Surprise Lake
- Fivemile Lake
- Lake Killarney
- Lake Geneva
- North Lake
- Steel Lake
- Lake Fenwick
- Angle Lake
- Bay Lake
- Crescent Lake
- Horseshoe Lake
- Wye Lake
- Wicks Lake
- Long Lake
- Lake Meridian
- Bonney Lake
- Lake Tapps
- Dolloff Lake
- Bow Lake
- Waughop Lake
- Wapato Lake

Wind Patterns


WA Dept. of Ecology. 2002. King County mainland soil study.
Lakes within predicted deposition zone significantly higher in As and Pb

**As vs. Pb in Surface Sediments**

- Crescent
- Killarney
- Fenwick
- Angle
- Lake Geneva
- Genesee
- Meridian
- Fivemile
- Long Bridge
- Spanaway
- Genesee
- Horseshoe
- Bay
- Angle
- Wicks
- Surprise
- Steel
- Snake
- Steilacoom
- Two
- Different Sources?

Two Different Sources?

- **R^2 = 0.8932**
- **R^2 = 0.6978**

**As in Sediment Cores**

- **As (mg/kg dry sediment)**
- **Depth in core (cm)**

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**Sediment Summary**

- Surface sediments in 10 of 12 lakes in deposition zone exceed probable effects concentration of 33 ppm As and 128 ppm Pb
  - PEC = "above which negative effects are likely to be observed after a period of exposition"
- Lake Killarney and Angle Lake show highest sediment concentrations at sediment surface
- Ongoing inputs?
- Vertical migration?
**Sediment/Water Transfer**

- **Basic Red/Ox Chemistry**
  - Oxidized
    - \( \text{Fe}^{3+} \) (oxidized)
    - \( \text{AsO}_4^{3-} \) (arsenate)
    - \( \text{AsO}_3^{3-} \) (arsenite)
  - Reduced
    - \( \text{HS}^- \) (sulfide)
    - \( \text{AsO}_3^{3-} \) (arsenite)

- **Effect of Eh and pH on As/Fe/S**
  - Primary inorganic forms:
    - Arsenate (As(V))
    - Arsenite (As(III))
    - Ferric (Fe(III))
    - Ferrous (Fe(II))
  - Redox and pH influence speciation and mobility.

- **Arsenic Remobilization**
  - WARM: Thermocline barrier to mixing oxygen
  - COOL: Organic forms of As (CO_3, HCO_3, AsO_3^2-)

- **Lake Meridian, Angle Lake, North Lake, Lake Killarney**
  - Temperature and Dissolved Oxygen (DO) profiles
  - Average Total Arsenic Concentration (ppb)

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DO vs PO₄ in Select Lakes

Filtered vs. Unfiltered

Dissolved Arsenic Speciation

Proposed Model for As Mobility in Presence of Oxygen
Questions to Address in Research

- What is the mix of water quality parameters to measure to predict As mobility in urban lakes?
- Does the presence of high levels of dissolved As in surface waters increase biotic uptake by phytoplankton, zooplankton, and fish?
- Would fish bioaccumulation become an issue under these conditions?
- How might this be important to freshwater sediment criteria development?

Bioindicators of Metal Toxicity

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To All My UW Tacoma and Bellarmine Researchers!
Links page

- Dr. Jim Gawel (jimgawel@uw.edu)

- Environmental Sciences and Studies at University of Washington Tacoma:
  [http://www.tacoma.uw.edu/interdisciplinary-arts-sciences/courses/environmental-studies](http://www.tacoma.uw.edu/interdisciplinary-arts-sciences/courses/environmental-studies)

- University of Washington Superfund Research Program:

- US EPA Region 10:
  [http://www.epa.gov/aboutepa/region10.html](http://www.epa.gov/aboutepa/region10.html)

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- Superfund Research Program - National Institute of Environmental Health Sciences (NIEHS)